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ABSTRACT

In this research on motor short-term memory it was hypothesized that subjects making free-selected movements would evidence superior reproduction accuracy over subjects making preselected movements, whose reproduction performance would be superior to subjects making constrained movements. Subjects making free-selected movements were allowed to determine distance moved, terminal location, and speed of response. Subjects made preselected movements under similar conditons, except that the experimenter reminded them of the importance of preselections, as well as to move at a slow but continuous speed, and not to choose the same movement more than once during the sequence. When making constrained movements, subjects moved at a slow but continuous speed to a terminal location that was chosen at random by the experimenter. The methodology and design of this research is described in this report. Results indicated that the reproduction accuracy of free-selected movements were superior to that of preselected movements, which in turn exhibited less reproduction error than constrained movements. However, those performers making preselected movements were no less variable than those making constrained movements. A discussion of the possible bias provided by experimenter instruction is included. (JD)

THE FREE-SELECTION EFFECT IN MOTOR SHORT-TERM MEMORY

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The superior reproduction accuracy of active, voluntary movements over constrained or passive movements, termed the preselection effect, is considered to be a general phenomenon in motor short-term memory research (Kelso & Wallace, Note 1). This effect has been substantiated in studies of location and distance reproduction (Stelmach, Kelso, & Wallace, 1975), processing demands of movements (Stelmach, Kelso, & McCullagh, 1976), feedback augmentation (Kelso & Frekany, in press) and deprivation (Kelso, in press), and corollary discharge versus cognitive planning (Kelso, 1977a). However, one particular methodological flaw has not been considered as a possible artifact in any of the studies, including a study in which it was concluded that the preselection effect was not due to faults in methodology (Wallace, Kelso, & Godoman, in press).

Perhaps the major procedural drawback of every preselection study has been the operational definition applied to subjects making preselected movements. A preselected movement is supposed to be a voluntary, subject-defined, active movement. The adjective "voluntary" connotes that <u>every</u> parameter of the movement is designated by the subject. However, in all the "preselection effect" studies to date, subjects in the preselected condition moved under restraints provided by the experimenter. These subjects were instructed to disperse their movements equally among the short, medium, and long response sectors and to move to these response sectors in a slow, but continuous manner. Furthermore, these same subjects were reminded of the importance of preselecting a movement. Therefore, truly voluntary, totally subject-defined, active criterion movements were never made in any of these studies. This procedural weakness leads to the question of whether or not performance differences would exist between subjects making preselected movements as previously defined, and subjects making movements in which all the parameters are self-determined (free-selected movements).

It was the purpose of this study to determine if the preselection effect was truly a general phenomenon of motor short-term memory or simply due to flaws in the methodologies of previous experiments. These flaws were identified as the operational definition of a preselected movement, and the possible positive biasing effects instructions to the preselected group may have had when compared to the constrained group. It was hypothesized that subjects making free-selected movements would evidence superior reproduction accuracy over subjects making preselected movements, whose reproduction performance would be superior to subjects making constrained movements.

METHODS

Subjects

Male (N=12) and female members (N=12) ($\bar{X}$ age = 25.39 yrs.) enrolled in a graduate class in research methods conducted in the Movement Science Program at Florida State University volunteered to be participants in this study. The criteria for allowing the volunteers to participate were not based on the gender of each subject or their hand preference, but rather on their naivete about the experiment and the hypotheses under investigation. The equal number of male and female participants occurred strictly by chance.

Apparatus

The test apparatus was a curvilinear repositioning task. A metal pointer 25 cm long, was attached to a flat metal base (36 cm X 64 cm). The pointer rotated on a ball bearing mechanism, such that the pointer could be moved through a range of 200° in the horizontal plane.

To facilitate a subject's movement of the pointer, a pillarlike handle, 8.25 cm high, was attached vertically to the pointer 14 cm from the axis of rotation. On top of the base, lines and numerals were engraved so that degrees of rotation were represented in one and five unit increments. Finally, a portable screen with a black cloth draped over the frame was mounted to the base and was positioned on the subject's side of the display to prevent viewing of the pointer and the degree markings during movement.

Procedure

Each individual was blindfolded before entering the testing area. Upon entering it, a treatment presentation order was randomly assigned to that subject. The treatment conditions were three types of movements that the subject made with the right hand from right to left. The movement conditions were free-selected, preselected, and constrained. When making free-selected movements, subjects were allowed to determine all parameters of their response, e.g., distance moved, terminal location, and speed of response. When subjects made preselected movements, they did so under conditions similar to the free-selected movements, except that the experimenter reminded the subjects of the importance of preselection, as well as to move at a slow but continuous speed, and not to choose the same movement more than once during the sequence. When making constrained movements, subjects moved at a slow but continuous speed to a terminal location which was chosen at random by the experimenter. The dispersion of movements into response sectors was not considered under any movement condition because it was not found to be a major factor in previous studies. (Stelmach, et al., 1975, 1976).

With the apparatus placed on a table, the subject was seated facing the task so that the right shoulder was aligned with the starting position of the pointer. All subjects performed 10 trials under each movement condition for a total of 30 trials. Each movement was preceded by a set of commands which were presented verbally by the experimenter to the subjects at 2 sec intervals. These commands were directly related to the movement condition. For the free-selected movement, subjects were instructed to covertly select a movement upon hearing the command "Select." Following this, the subject was issued the command "Grasp," at which time the subject took hold of the handle. This was followed by the command "Move," and the subject rotated the pointer to the chosen location (criterion movement). After a 2 sec delay at the terminal location, the command "Release" was given to the subject, who then let go of the handle. The experimenter then returned the handle to the starting position (0°), after which the subject was told to "Regrasp" the handle. The command "Replicate" was then issued and the subject had to reproduce the criterion movement. Upon completion of the reproduction movement, the subject was told to release the handle and to return the right hand to a resting position on the table. This constituted a trial, and the same sequence of commands was issued to the subject prior to each trial. No KR was administered at any time, during or between trials. Distance and location cues were reliable on both the criterion and reproduction movements. The intertrial interval was 5 sec as determined with a hand-held Meylan 30 sec stopwatch.

After 10 trials, subjects were given a 1 min rest period, then received commands pertaining to the next movement condition. For the preselected condition, the commands, and the sequence in which they were given, were identical to those commands in the free-selected condition. In addition, subjects were reminded of the importance of preselection,

the necessity of a slow but continuous movement, and they were also requested not to select the same movement more than once during the movement sequence.

The final movement condition was one in which subjects moved in a constrained mode following a 1 min rest upon completion of the previous set of 10 trials. They received no "Select" command, but they were instructed to move to a mechanical stop randomly chosen by the experimenter within a restricted range of 5° to 100°. The command sequence relative to this movement was "Grasp, Move, Release, Replicate, and Release;" and these commands were administered by the experimenter prior to each trial.

Design

A within-subjects design was used because of the small sample size so that individual differences, i.e., anatomical, physiological, or psychological, which may have existed had a between-subjects design been used with this sample, would be accounted for across movement conditions (cf. Wallace, et al., in press). Each subject received the three different treatment conditions with the order of administration of these treatments randomly assigned to each subject so that order effects were neutralized (Tuckman, 1972).

RESULTS

A preliminary analysis of variance was conducted on the dependent variables of absolute error (AE), variable error (VE), and constant error (CE), to determine if there was a main effect for gender. Since all the results were non-significant, the scores of male and female sub-

jects were combined for further analysis.

A 6 X 3 (order X movement condition) factorial analysis of variance was performed on each dependent variable. None of the analyses yielded an order main effect, which was interpreted as support for the Wallace et al. (in press) conclusion that the preselection effect was not due to a flaw in the methodology of the administration of treatments. Thus, the lack of a significant order effect may be considered as further support for the generality of the preselection phenomenon in motor short-term memory.

There was a significant main effect for movement condition ($F_{2,36}=11.70$, $p<.01$) for AE, but not for CE. Descriptive data for this factor are shown in Table 1. A Newman-Keuls multiple comparisons test was performed on these means, and it was found that the free-selected group exhibited less reproduction error than the preselected group, which was significantly more accurate than the constrained group. Similarily, a movement condition main effect was found when VE was analyzed ($F_{2,44}=3.63$, $p<.05$). Follow-up tests on these means (see Table 1) were interpreted as evidence that the free-selected group was significantly less variable in reproduction performance than the constrained group, while the free-selected and preselected groups, and the preselected and constrained groups, were not significantly different from each other.

Insert Table 1 about here

Discussion

The hypothesis that the reproduction accuracy of free-selected

movements would be superior to that of preselected movements, which would in turn exhibit less reproduction error than constrained movements was supported. Additionally, less variability was exhibited by subjects performing in the free-selected response mode. However, a surprising result was that those performers making preselected movements were no less variable than those persons making constrained movements. This result was not expected, especially since the reproduction accuracy of the preselected group was superior to the reproduction accuracy of the constrained group with AE as the dependent variable.

Results of this study are indicative of the superior reproduction accuracy of subjects making active, voluntary movements compared to subjects making constrained movements (cf. Kelso, 1977a, 1977b, in press; Kelso & Frekany, in press; Marteniuk, 1973; Stelmach & Kelso, 1977; Stelmach, et al., 1976; Wallace & Stelmach, 1975). Additional support for this conclusion is provided by the use of a free-selected movement group in this study. This group, uninfluenced by any instructions to disperse movements equally among response sectors or to remember the importance of selecting a movement, was included to counteract any possible biasing effect caused by the instructions to the preselected group, which may have favored the preselected group over the constrained group. Since subjects in the free-selected group performed better than subjects in both the preselected and constrained groups, it can be concluded that the reproduction accuracy of a subject making active and completely voluntary movements is superior to any other type of movement.

The superior reproduction accuracy of completely voluntary movements may also be taken as evidence that the instructions given to subjects making preselected movements in previous studies did not bias the outcomes. If the instructions were a source of positive bias, then

there should have been no difference in the reproduction accuracy of the free-selected group compared to the constrained group in the present study, because neither group received any directions prior to their movement. However, the free-selected movement was reproduced significantly better than the constrained movement, discounting any interpretation that instructions to the preselected group biased the results. Furthermore, the reproduction accuracy of free-selected movements was superior to that of preselected movements. Thus, although instructions to the preselected group are not a source of positive bias which can affect performance, the instructions may have another effect on the reproduction accuracy of preselected movements.

The data may be interpreted as support for the position that there is a difference in the processing of information when two distinct types of voluntary movements are made. Although it is true that a person making preselected movements is aware of the movement goal, the instructions provided by the experimenter may serve as a source of interference. While the subject covertly chose a movement in the preselected condition, that subject had to be consciously aware, not only of the importance of preselection, but of a random selection of movements. Subjects were required to preselect a different movement on each trial so that no movement was repeated during the testing sequence. If the instructions did not interfere with the subject's selection of a movement and the processing of cues associated with that movement, then no performance differences between preselected and free-selected movement groups should have occurred. However, the interference notion would seem to be supported, as the free-selected movement group performed significantly better than the preselected movement group.

The explanation that attention to the instructions may be a source of interference during the encoding of the movement cues associated with preselected movements could account for the lack of a significant difference in performance variability between the preselected and constrained groups, even though the former group was significantly more accurate during reproduction than the latter group. Subjects making preselected movements were consciously aware of the instructional set, the result being that attentiveness to the instructions possibly served as a source of interference. Therefore, some forgetting of the chosen movement should occur because the movement goal was degraded in some manner and was no longer clear to the performer. It is as if the subject was attempting to reconstruct the original movement image in memory, even though some information was "missing." If the reconstructed image was imperfect, a more variable reproduction response than that associated with free-selected movements should result, as was the case.

The extent of the response variability of preselected movements would then depend on the amount of interference caused by attention to the instructions. The findings of this study have been interpreted as preliminary evidence that the information load of the instructions was sufficient to cause a deterioration of the goal-image associated with preselected movements. This deteriorated motor image led to a less accurate and more variable response than the motor image of free-selected movments. However, as an explanation of the non-significant differences in response variability between preselected and constrained movements, the interference notion must await future research.

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TABLE 1

DESCRIPTIVE DATA OF MOVEMENT CONDITIONS

	Free-Selected	Pre-Selected	Constrained
AE	3.00°	4.95°	6.50°
VE	2.80°	4.64°	5.97°
CE	-.21°	-.20°	-.11°